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Research Paper

Effect of integrated nutrient management on crop productivity and changes in soil fertility in maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping sequence

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ABSTRACT

The study was conducted during 2009–11 at Ranchi, Jharkhand, to study the effect of integrated nutrient management practice on system productivity and change in soil-fertility status under maize (*Zea mays* L.)–-wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping sequence in the field under long-term experiment since 1983. Continuous application of organic sources farmyard manure (FYM), cut paddy straw and green *karanj* (*Pongamia* sp. leaves) along with chemical fertilizers improved grain yield and soil-fertility status. Substitution of 50% N through FYM and 50% recommended dose of fertilizer (RDF) in maize and 100% RDF through inorganic fertilizer in wheat recorded the highest system productivity (wheat-equivalent yield 8.2 t/ha), net returns (₹51,196.0/ha), benefit: cost ratio (0.93) and nutrient uptake (209.2, 30.4 and 196.0 kg N, P and K/ha) in maize–wheat cropping system. Soil-fertility status in terms of pH, organic carbon, available N, P, K, S and B after 28 cycles of cropping, fertilizer and manure application were also affected by nutrient-management practices. Available S was above critical level for all the treatments, while available B varied from 0.27 to 0.54 ppm after 28 cycles of cropping. Continuous cropping with combined application of organic manure along with chemical fertilizers was found to be effective not only, for increasing grain yield of crops in maize–wheat cropping system, but also, for higher benefit: cost ratio, nutrient uptake and maintenance of soil-fertility status.

Key words : Economics, Integrated nutrient management, Nutrient uptake, Soil-fertility status, System productivity and Wheat-equivalent yield

Fertilizers played a vital role in agriculture production and productivity in India but continuous and imbalanced use of chemical fertilizer creates problem in the production potential and deterioration of soil health. Use of chemical fertilizer in combination with organic manure is required to improve the soil health (Bajpai *et al*., 2006). In this regard, long-term fertilizer experiments are considered as vital tools to examine sustainability of intensive cropping system and the impact of continuous application of integrated nutrient management practices on crop productivity and soil health. Maize–wheat is the third most important cropping system after rice–wheat and rice–rice in India, and is grown on about 1.80 million ha each year (Jat *et al*., 2012). Maize, a crop with high yield and market potential, fits well into rice–wheat systems by replacing rice.

Alfisols of eastern India have problems of low water and nutrient-holding capacity, low soil organic carbon, high P-fixation capacity, besides soil acidity problems (Singh, 2007). Majority of the soils in Jharkhand are deficient in nitrogen, phosphorus and organic matter to release native as well as fixed nutrients, ultimately affecting the soil health and crop productivity. Hence, there is a need to evaluate the effect of continuous application of chemical fertilization alone and in combination with organic source of nutrients, viz. FYM, paddy straw or green *karanj* leaf on crop productivity and changes in soil fertility of an acid soil under maize–wheat cropping system.

MATERIALS AND METHODS

A long-term nutrient management experiment initiated in the rainy (*kharif*) season of 1983 under AICRP on Cropping System Research on Maize-Wheat system at Birsa Agricultural University, Ranchi. The experiment was laid out in randomized block design in 50.4 m^2 for each plot size with 12 treatments, replicated 3 times. Treatments comprised T_1, $N_0P_0K_0$ - $N_0P_0K_0$; T_2, 50% recommended dose of fertilizer (RDF) - 50% RDF; T_3, 50 % RDF - 100% RDF; T_4, 75% RDF -75% RDF; T_5, 100% RDF - 100% RDF; T_6, 50% N through FYM+ 50% RDF

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- 100% RDF; T_7, 25% N through FYM + 75% RDF - 75% RDF; T_8, 50% N through cut paddy straw + 50% RDF - 100% RDF; T_9, 25%N through cut paddy straw + 75% RDF - 75% RDF; T_{10}, 50% N through green *karanj* leaves + 50% RDF - 100% RDF; T_{11}, 25% N through green *karanj* leaves + 75% RDF - 75% RDF and T_{12}, 50 kg - 50 kg urea/ha for maize and wheat respectively. The recommended fertilizer dose (100% RDF) of N, P and K was 100, 21.83 and 20.83 kg/ha respectively, for both the crops, of which one-third of N and full dose of P and K were applied basal. The remaining N was divided into 2 equal parts and applied 21 and 45 days after sowing as per treatments. The sources of N, P and K were urea, single superphosphate and muriate of potash respectively. Organic manure, viz. FYM and crop residues, viz. cut paddy straw (CPS) and green *karanj* leaf (GKL), were applied on the basis of N content as per the treatment 15 to 20 days before sowing in the rainy season of every year. This experiment was being conducted for last 28 years without any change and break in the treatments. But crop varieties were changed for avoiding disease infestation in crops. The experimental site situated at 23°17' N and 85°19' E with an altitude of 625.2 m above the mean sea-level in Jharkhand state of India. This place has sub-tropical climate characterized by hot and dry summer, comparatively cool rainy season followed by moderate winter. The soil was sandy clay loam in texture with pH (6.5), organic carbon (0.41%), available N (255.0 kg/ha), P (14.19 kg/ha) and K (195 kg /ha). This study was undertaken on the above long-term nutrient management experiment with Maize ‘HQPM 1’ and Wheat ‘K 9107’ during 2009–10 and 2010–11. Total cobs from net plot area of each plot were harvested, sun-dried and shelled. The seeds were cleaned, sun-dried and weighed. Stones from the net plot area were also weighed. Similarly, for wheat harvested bundles from each net plot were threshed, cleaned, sun-dried and weighed separately and grain and straw yield was recorded and expressed in t/ha.

Agronomic use efficiency of system was calculated based on the difference in economic yield (WEY) of the system obtained for the treated plot (RDF) from the untreated plot (control) by using the following formula:

$$\text{Agronomic use efficiency of nutrient (kg grain/kg nutrient added)} = \frac{\text{(WEY (kg/ha) in treated plot–WEY (kg/ha) in control plot)}}{\text{Nutrient added (kg/ha)}}$$

Total N content in the plant parts were estimated by modified Kjeldahl digestion and distillation method. Total P and K in plant parts were digested in triacid mixture (HNO_3 : $HClO_4$: H_2SO_4 in 10:4:1 ratio on volume basis). Total P content was determined colorimetrically at 440 nm following Vanado- molybdate nitric acid yellow-colour method. Total K of plant sample was determined by flame photometer from the same aliquot obtained for total P as described by Tandon (1999). Nutrient uptake of each nutrient (N, P and K) was calculated separately for grain and straw /stover and stone by multiplying its content with respective grain and straw / stover and stone yield values. In order to get the total uptake of nutrient**,** the uptake values for grain and straw/ stover and stone were added up. Uptake values were expressed in kg /ha.

Economics of the cropping system was calculated based on the additional expenditure incurred due to different treatments along with the normal cost of cultivation in raising crops. Benefit: cost ratio (B:C) was calculated based on the ratio of net profit to total cost incurred.

Post-harvest surface soil samples were collected treatment-wise from all replications of ongoing permanent manurial trial after harvest of wheat crop during 2009–10 and 2010–11. Soil pH was determined in soil water suspension of 1:2.5 :: soil: water, after stirring for 30 minutes using Systronic make pH meter as described by Jackson, (1973). Organic carbon content of soil samples were determined by Walkley and Black rapid titration methods as described by Baruah and Barthakur (1997).

Available nitrogen in soil was determined by alkaline potassium permanganate method of Subbiah and Asija (1956). Available soil P content was extracted by Bray P_1 extractant (0.03 N NH_4 F in 0.025 N HCI solutions) and estimated colorimetrically at 660 nm using Systronics make colorimeter. Available potassium content in soil samples were extracted in 1:5 : soil : neutral normal ammonium acetate (pH - 7.0) suspension by shaking for 5 minutes and filtered. Potassium was then estimated in the extract with the help of Elico make flame photometer. Available sulphur content in soil was extracted in 1:5 :: soil : 0.15% $CaCl_2$ suspension by shaking for 30 minutes and filtered. Sulphur was then estimated in the extract turbidimetrically at 440 nm with the help of Systronics make colorimeter. Available boron content in soil wass extracted with boiling water in 1:2 :: soil: water suspension after 5 minutes of boiling under refluxed conditions and estimated colorimetrically at 430 nm using Azomethine-H as color developing reagent with the help of Systronics make colorimeter as described by Baruah and Barthakur (1997).

RESULTS AND DISCUSSION

Grain yield

The maximum grain yield of maize, wheat as well as system was recorded with 50% N through FYM + 50% N through inorganic fertilizer in maize and 100% RDF in wheat. Pooled mean data for wheat-equivalent yield under maize–wheat cropping system varied from 1.62 to 8.20 t/

ha and influenced by INM practices (Table 1). The increase in mean grain yield was 0.53 t/ha for maize, 0.66 t /ha for wheat and 1.08 t /ha for wheat equivalent yield as compared to recommended dose of fertilizers (100% RDF) both in maize and wheat. This is in agreement with the results of long term fertilizers experiments carried out in different agroclimatic situations of the country (Singh and Wanjari, 2013). Application of 50% N through FYM + 50% through chemical fertilizer in maize and 100% RDF in wheat was significantly superior to 100% recommended fertilizer applied to both the crops and remained on a par with 25% N substitution through FYM and 75% through inorganic source in maize and 75% RDF in wheat. Substitution of N through cut paddy straw or green *karanj* leaf significantly reduced the grain yield as well as wheat-equivalent yield of the system and reduction in grain yield was up to 0.29 t/ha as compared to recommended dose of fertilizers, i.e. 100% RDF applied in both maize and wheat. Similar to grain yield of crops, agronomic use-efficiency of nutrient-management practices (Table 1) was also highest for treatment receiving 50% N through FYM + 50% N through inorganic fertilizer in maize and 100% RDF in wheat (23.1 kg grain/kg nutrient added), followed application of 25% N through FYM + 75% N through inorganic fertilizer in maize and 75% RDF in wheat (22.0 kg grain/kg nutrient added). This finding indicated that the combined application of well-decomposed organic nutrient source and chemical fertilizers proved to be superior to sole inorganic fertilizer application. Pathak *et al*. (2005) and Jat *et al*. (2012) also observed similar findings. However, substitution of a part of N through rice straw and fresh *karanj* leaf did not perform well possibly due to slow mineralization of organic N leading to its deficiency during growing period of maize.

Nutrient uptake

Pooled mean data for total N, P and K uptake (kg/ha) by maize and wheat are presented in Table 2. Total nutrient uptake varied from 17.2 to 103.0, 2.2 to 13.6 and 14.7 to 94.4 kg N, P and K/ha for N, P and K, respectively, in maize; 21.0 to 106.2, 2.9 to 16.8 and 20.4 to 101.3 kg N, P and K/ha for N, P and K, respectively, in wheat; and 38.2 to 209.2, 5.1 to 30.4 and 35.1 to 195.7 kg N, P and K/ha for N, P and K, respectively, by the system. Higher nutrient uptake for INM practices was due to combined application of organics and inorganic fertilizers. Significantly highest total N, P and K uptake were recorded under treatment receiving 50% N through FYM + 50% N through inorganic fertilizer in maize and 100% RDF in wheat. Higher biomass production may be ascribed as the most pertinent reason for higher uptake of nutrients. Higher availability of nutrients due to residual effect of organic sources thereby improving physiological and metabolic functions inside the plant might have been responsible for better expression of growth parameters, yield and nutrient uptake. The findings confirm those of Mahapatra *et al*. (2007), Kumar (2008), Kumar and Dhar (2010).

Economics of the system

Pooled data on gross return, net return and benefit: cost

Table 1. Grain yield of maize and wheat, wheat-equivalent yield (WEY) and agronomic use efficiency of the system as affected by nutrient management practices (pooled data of 2 years).

Treatment *Kharif*	*Rabi*	Maize (t/ha)	Wheat (t/ha)	WEY (t/ha)	Agronomic use efficiency (kg grain/kg nutrient added)
$N_0P_0K_0$	$N_0P_0K_0$	0.81	0.98	1.62	-
50% RDF	50% RDF	2.43	2.65	4.59	20.8
50% RDF	100% RDF	2.51	3.89	5.90	20.0
75% RDF	75% RDF	2.72	3.41	5.59	18.5
100% RDF	100% RDF	3.84	4.05	7.12	19.3
50% N (FYM) + 50% RDF	100% RDF	4.37	4.71	8.20	23.1
25% N (FYM) + 75% RDF	75% RDF	3.83	4.07	7.12	22.0
50% N (CPS) + 50% RDF	100% RDF	3.55	4.00	6.83	18.3
25% N (CPS) + 75% RDF	75% RDF	3.40	3.60	6.31	18.8
50% N (GKL) + 50% RDF	100% RDF	3.10	3.80	6.27	16.3
25% N (GKL) + 75% RDF	75% RDF	2.67	3.51	5.64	16.1
Farmer's practice urea @ 50 kg/ha	Farmer's practice urea @ 50 kg/ha	1.02	1.25	2.01	9.7
SEm±		0.18	0.21	0.36	
CD (P=0.05)		0.53	0.60	1.01	
CV (%)		11.29	10.93	11.23	

(B:C) ratio (Table 3) were affected by nutrient management practices. Mean gross return varied from ₹21,003 to ₹1,06,462/ha with a net return of ₹18,704 to ₹51,196/ha and benefit: cost ratio of –0.47 to 0.93 for the maize–wheat cropping sequence. The treatment receiving 50% N through FYM + 50% RDF through inorganic fertilizer in maize and 100% RDF in wheat recorded the highest economical return (₹51,196) as well as with higher benefit: cost ratio (0.93) over the rest of the treatments. Treatment receiving 50% N through FYM + 50% RDF through inorganic fertilizer in maize and 100% RDF in wheat recorded significantly higher net return and benefit: cost ratio over the recommended fertilizer practice of 100% RDF in both crops (maize and wheat). The FYM substitution up to 50% was observed to be the most effective INM practice as compared to other sources.

Soil properties

Pooled mean data for soil pH, organic carbon, available N, P, K, S and B after 28 crop cycling of maize–wheat

Table 2. Effect of integrated nutrient management practices on nutrient uptake by maize and wheat in maize–wheat cropping system (pooled data of 2 years).

Treatment		Nutrient uptake(kg/ha)					
Kharif	*Rabi*	Maize (pooled data of 2 years)			Wheat (pooled data of 2 years)		
		N	P	K	N	P	K
$N_0P_0K_0$	$N_0P_0K_0$	17.2	2.2	14.7	21.0	2.9	20.4
50% RDF	50% RDF	54.0	6.9	45.7	57.9	8.4	53.3
50% RDF	100% RDF	56.2	7.3	48.9	86.4	12.8	82.3
75% RDF	75% RDF	61.8	7.9	54.3	75.4	11.2	71.4
100% RDF	100% RDF	89.4	11.9	79.6	90.9	13.8	86.4
50% N (FYM) + 50% RDF	100% RDF	103.0	13.6	94.4	106.2	16.8	101.3
25% N (FYM) + 75% RDF	75% RDF	88.4	11.7	76.9	90.3	13.7	84.2
50% N (CPS) + 50% RDF	100% RDF	81.3	10.6	71.4	89.4	13.4	83.8
25% N (CPS) + 75% RDF	75% RDF	77.3	9.9	68.0	79.3	11.4	73.0
50% N (GKL) + 50% RDF	100% RDF	71.1	9.4	63.6	84.8	12.7	78.5
25% N (GKL) + 75% RDF	75% RDF	60.1	7.9	52.7	77.3	10.9	71.4
Farmer's practice urea @ 50 kg/ha	Farmer's practice @ 50 kg/ha	21.9	2.7	19.2	27.8	3.8	26.5
SEm±		3.17	0.42	3.37	4.67	0.71	4.60
CD (P=0.05)		9.02	1.18	9.59	13.30	2.03	13.09
CV (%)		8.42	8.47	10.15	10.95	11.24	11.47

Table 3. Effect of integrated nutrient management practices on economics of maize–wheat cropping system (pooled data of 2 years).

Treatment *Kharif*	*Rabi*	Gross returns (×10^3₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
$N_0P_0K_0$	$N_0P_0K_0$	21.0	-18.7	-0.47
50% RDF	50% RDF	59.5	12.9	0.28
50% RDF	100% RDF	76.3	26.3	0.52
75% RDF	75% RDF	72.3	22.4	0.45
100% RDF	100% RDF	92.3	38.8	0.73
50% N (FYM) + 50% RDF	100% RDF	106.5	51.2	0.93
25% N (FYM) + 75% RDF	75% RDF	92.3	39.7	0.75
50% N (CPS) + 50% RDF	100% RDF	88.5	28.0	0.46
25% N (CPS) + 75% RDF	75% RDF	81.8	23.9	0.41
50% N (GKL) + 50% RDF	100% RDF	81.3	30.2	0.59
25% N (GKL) + 75% RDF	75% RDF	73.1	22.5	0.45
Farmer's practice urea @ 50kg/ha	Farmer's practice urea @ 50kg/ha	26.8	-14.2	-0.35
SEm±		4.0	1.4	0.03
CD (P=0.05)		11.7	38.4	0.08
CV (%)		9.57	10.33	11.91

Selling Price (₹/q): Maize, ₹1,000; stover, ₹20; maize stone, ₹100; wheat-grain, ₹ 1,250; wheat straw, ₹20

Table 4. Effect of integrated nutrient Management practices on fertility status of soil after 28 years of cropping, fertilizer and manure application (pooled data of 2 years).

Treatment		pH	SOC (%)	Available N (kg N/ha)	Available P (kg P/ha)	Available K(kg K/ha)	Available S (kg S/ha)	Available (ppm)
Kharif	*Rabi*							
$N_0P_0K_0$	$N_0P_0K_0$	6.28	0.35	225.6	15.4	146.7	21.7	0.28
50% RDF	50% RDF	6.15	0.36	240.1	48.8	134.6	27.8	0.36
50% RDF	100% RDF	6.27	0.37	247.6	61.9	132.1	26.0	0.33
75% RDF	75% RDF	6.20	0.38	245.4	64.5	129.7	36.4	0.36
100% RDF	100% RDF	6.12	0.40	272.2	100.5	127.3	43.4	0.39
50% N (FYM) + 50% RDF	100% RDF	6.77	0.60	375.2	112.8	144.3	30.4	0.56
25% N (FYM) + 75% RDF	75% RDF	6.43	0.51	329.5	94.1	139.4	27.8	0.47
50% N (CPS) + 50% RDF	100% RDF	6.28	0.50	321.1	85.5	134.6	26.0	0.47
25% N (CPS) + 75% RDF	75% RDF	6.25	0.45	293.1	74.3	129.7	30.4	0.39
50% N (GKL) + 50% RDF	100% RDF	6.27	0.47	305.2	74.6	132.1	36.4	0.33
25% N (GKL) + 75% RDF	75% RDF	6.33	0.43	283.2	70.5	129.7	27.8	0.36
Farmer's practice urea @ 50 kg/ha	Farmer's practice urea @ 50 kg/ha	6.03	0.34	229.3	14.6	120.1	26.0	0.33
SEm±		0.15	0.03	19.68	4.48	8.15	0.92	0.01
CD (P=0.05)		0.44	0.08	57.74	13.13	23.90	2.70	0.03
CV (%)		4.19	10.67	12.14	11.37	10.58	5.31	5.19

cropping were affected by nutrient management practices are given in Table 4. Variation in soil pH was from 6.03 to 6.77 as compared to the initial value of 6.5; organic carbon varied from 0.35 to 0.60 as compared to initial value of 0.41%; available N varied from 225.6 to 375.2 as compared to initial value of 255.0 kg N/ha; available P varied from 14.6 to 112.8 as compared to initial value 14.2 kg P/ha and available K varied from 127.3 to 146.7 as compared to initial value 195.0 kg K/ha. Available S was above critical level for all the treatments, while available B varied from 0.28 to 0.56 ppm after 28 cycles of cropping. Under maize–wheat cropping system, combined application of 25–50% N through well-decomposed nutrient source, i.e. FYM in maize and 75-100 % RDF through chemical fertilizers to both the crops, was found beneficial in increasing the productivity of crops and improving soil fertility status as compared to sole application of chemical fertilizer. Application of well-decomposed organic manures solubilize soil nutrients, while application of fresh crop residue or green leaf immobilize the available nutrients resulting in reduction in available nutrients during crop growth. Combined application of FYM along with chemical fertilizers thus resulting in a significant improvement in available nutrient status of soil and enhance crop productivity. Similar results were obtained under different cropping sequences in different types of soils of India (Behera and Nand Ram 2004, Bajpai *et al.*, 2006, Laxminarayana, 2006).

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